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SHORT REPORT

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Using rangefinder binoculars to measure the behaviour and movement of European Shags *Phalacrocorax aristotelis* in coastal environments

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ABSTRACT
Human activity and development in coastal environments can pose threats to pursuit-diving seabirds. This study demonstrates that rangefinder binoculars can be used to provide useful measurements of the behaviour and movement of European Shags *Phalacrocorax aristotelis* in a small coastal area.

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In marine and coastal environments, human activity and developments can be in direct conflict with seabird activity (Dias *et al.* 2019). Pursuit-diving seabirds are particularly vulnerable to these potential conflicts in coastal environments, as they spend considerable amounts of time on, or beneath the water's surface when foraging (Waggitt & Scott 2014). Foraging seabirds can be negatively impacted by human activity via recreational vessels disturbing or preventing access to feeding areas (Velando & Munilla 2011), and/or fishing vessels accidentally injuring or killing birds in nets and with hooks (Christensen-Dalsgaard *et al.* 2019). There are also negative impacts associated with emerging developments such as marine renewable energy, particularly the risks of diving birds colliding with moving components of tidal stream turbines (Wilson *et al.* 2007) and flying birds colliding with offshore wind turbines (Drewitt & Langston 2006). Information on bird behaviour and movement in marine areas where threatening activities and developments occur can be used to identify and mitigate risk. For example, information on altitude and speed has been used to quantify the risk of flying seabirds colliding with moving components of offshore wind turbines (Cleasby *et al.* 2015). As many human activities and developments in coastal environments occur at small and specific locations (Carter 2013), and as foraging strategies could differ between locations and species (Waggitt *et al.* 2017), fine-scale and site-specific information on bird behaviour and movement is needed.

Collecting information on seabird behaviour and movement in small and specific locations is challenging. While biologgers (or 'tags') can record sub-surface and surface seabird behaviour and movement (reviewed by Ropert-Coudert *et al.* 2010), tags cannot record a behaviour unless programmed to, and it is often unknown where birds will travel once tagged. Currently, if we want to quickly investigate bird behaviour at a specific site, we cannot assume that biologgers will collect relevant data, as without prior research there is no guarantee a tagged bird will even travel to the study site. As biologgers are often attached to birds at their breeding colonies, tag deployment depends on there being accessible breeding colonies near the area of interest, which also cannot be guaranteed. In addition to biologgers, sonar (Williamson *et al.* 2015) and radar (McCann & Bell 2017) technologies have also been used to record sub-surface (via sonar) and surface (via radar) bird behaviour and movement in locations of interest. However, sonar is susceptible to acoustic interference from turbulence (Fraser *et al.* 2017), and radar is affected by sea-clutter (McCann & Bell 2017), potentially preventing the detection and tracking of birds in many scenarios. Moreover, neither sonar nor radar can currently discriminate among species, and have associated infrastructure (e.g. electronics,

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moorings, mountings and power supplies) which limit their wider application. Ideally, methods that record bird behaviour and movement should minimize environmental interference, discriminate between species, enable rapid implementation and be widely applicable.

Adaptations of traditional observational approaches may provide solutions to gaps in current seabird behaviour and movement methodologies. Solutions include the use of hand-held binoculars together with a laser-rangefinding device (i.e. Ornithodolite), or the use of binoculars that contain a means of measuring bearings/reticles in the eyepiece (i.e. rangefinder binoculars). The potential for an Ornithodolite to record information on bird behaviour and movement at small and specific locations has already been shown (Cole *et al.* 2018). However, although rangefinder binoculars have been used to record bird behaviour (Sponza *et al.* 2010), their suitability for recording bird movement remains untested. Compared to an Ornithodolite, rangefinder binoculars are easily available, portable, and relatively affordable, making them the more accessible of the two approaches. Therefore, this study investigated whether rangefinder binoculars can provide useful measurements on the behaviour and movement of a diving seabird in a small and specific location. The European Shag *Phalacrocorax aristotelis* was chosen to test our method because it is a pursuit-diving seabird commonly found in European coastal areas (Wanless & Harris 2004).

A single person performed 39 surveys (2–6 h, total = 160 h) between 26th May and 17th August 2018. Opticron™ Marine-2 (7×50) binoculars were used from a vantage point (VP) approximately 5 m above sea level on the coastline opposite Ynys Moelfre, Anglesey, UK (53.3523° N 4.2373° W) (Figure 1). This person was able to observe birds in a westerly, northerly and easterly direction from the VP. Recordings started when a bird was seen landing or sitting on the sea surface; recordings were never taken when a bird was in flight or ashore. A time (GMT), distance (m) and bearing (°) to the bird were taken every time it surfaced or dived. If the bird was not actively diving or surfacing (i.e. was sitting on the surface), time, distance, and bearing were instead recorded at 1 min intervals until the bird resumed diving. The distance and bearing were recorded using the reticles and compass in the eyepiece, respectively (Figure 2). The distance was estimated using formula 1:

$$\text{Distance} = \frac{\text{Height} \times 1000}{\text{Mils}} \tag{1}$$

where Height is the VP altitude (m), and Mils (mm) is the measurement from the horizon to the bird in the eyepiece. Bearings were recorded to the nearest 0°, and Mils were recorded to the nearest 2.5 mm. To increase the accuracy of distance calculations, the VP altitude was adjusted according to the tidal state (difference from mean water depth, m) at the time of observations. This adjustment increased and decreased the VP altitude depending on whether observations occurred nearer low or high water, respectively. The tidal state was provided at 1 h and 50 m resolution, represented the mean value up to 2 km from the VP, and was sourced from an existing TELEMAC hydrodynamic model (Robins *et al.* 2014).

Recordings continued until the bird flew out of the study site, was not relocated after a dive, or had moved out of sight (e.g. behind the island or a bend in the coastline). The distances and bearings recorded in the field, together with the VP coordinates, were later converted to coordinates to estimate the geographic positions of birds monitored within the study site. Only solitary birds were monitored, so that

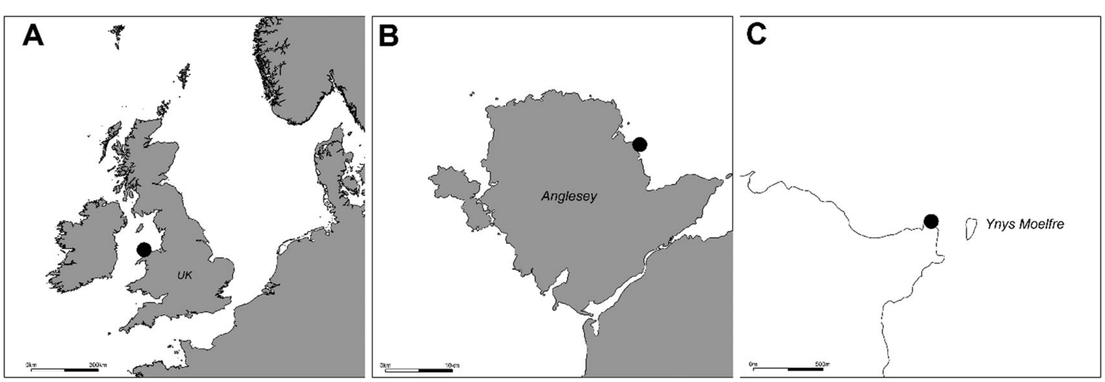

Figure 1. The location of the study site in Anglesey, UK (A–B). The vantage point was located approximately 5 m above sea level on the coastline opposite Ynys Moelfre (C). Both the study site and vantage point are indicated by a black circle in the appropriate map.

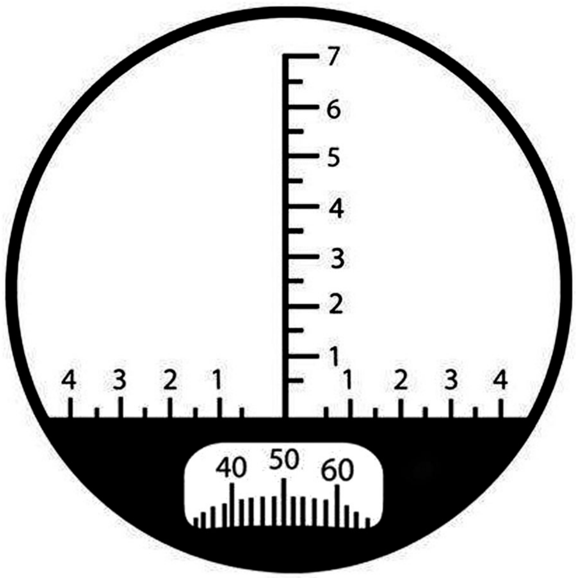

Figure 2. Example of the internal view provided by rangefinder binoculars, illustrating vertical axis reticles used to determine distance from the observer to the bird, and horizontal axis to record a compass bearing (0–360°) from the observer to the bird.

they could be tracked with confidence. When several solitary birds were present, individuals closer to the VP were given priority. Birds were not tracked during adverse weather (i.e. Beaufort scale >3 or heavy precipitation).

In total, 70 birds were observed during the surveys. Of these, 54 birds were observed for more than 10 min (mean = 16 min 28 s, total = 19 h 13 min). Estimated positions were between 18 and 1492 m from the VP. The resolution (defined as the maximum difference between potential positions) of each estimated position was calculated based upon the accuracy in the measurement of Mils (± 2.5 mm). Calculations showed that the resolution of positions was <1–1632 m, depending upon the tidal state at the time of observation and the magnitude of the distance between the bird and the observer. However, the resolution of positions was usually <100 m (75% of observations), regularly <50 m (61%) and often <10 m (43%). Therefore, it was decided to constrain measurements of bird behaviour and movement to the 30 birds where the resolution of positions was always <50 m and regularly <10 m (62% of observations). These 30 birds were observed at calculated distances up to 320 m from the VP, resulting in an effective study site coverage of approximately 0.26 km^2 (Figure 3).

Several metrics of bird movement were calculated for each bird: the area covered per minute (m^2 min^{-1}), the relative time underwater (%), dive intensity (dives per min), the mean dive length (s), the maximum dive length (s) and the repeatability of dive lengths. The area covered (m^2) was estimated using minimum convex polygons (MCP), performed using the 'mcp' function in the 'adehabitat HR' package (Calenge 2006) in R 3.5.1 (R Core Development Team 2018). While estimates from MCP are considered suspect in home-range analyses (Borger *et al.* 2006), these approaches were considered suitable for simple

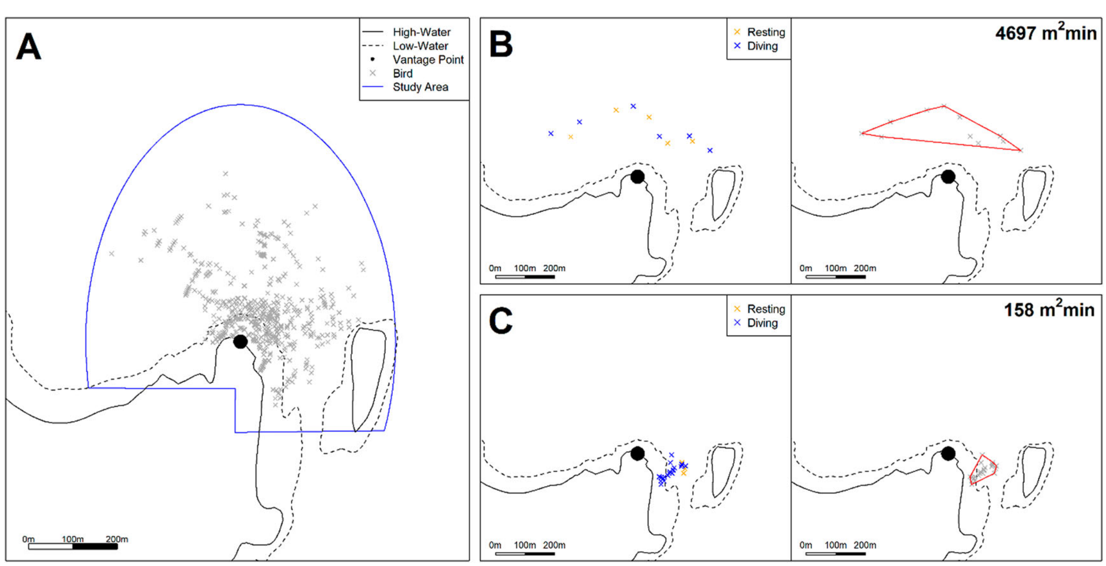

Figure 3. Calculated positions of 30 European shag *Phalacrocorax aristotelis* alongside Ynys Moelfre, Anglesey, UK (A). Also shown are examples of recorded behaviour and estimations of area covered per minute (m^2 min) for 2 of these 30 birds (B and C). Behaviour and movements of birds were recorded and calculated, respectively, using rangefinder binoculars from a vantage point ~5 m above mean sea level. Minimum Convex Polygons (MCP) approaches were used to estimate the area covered.

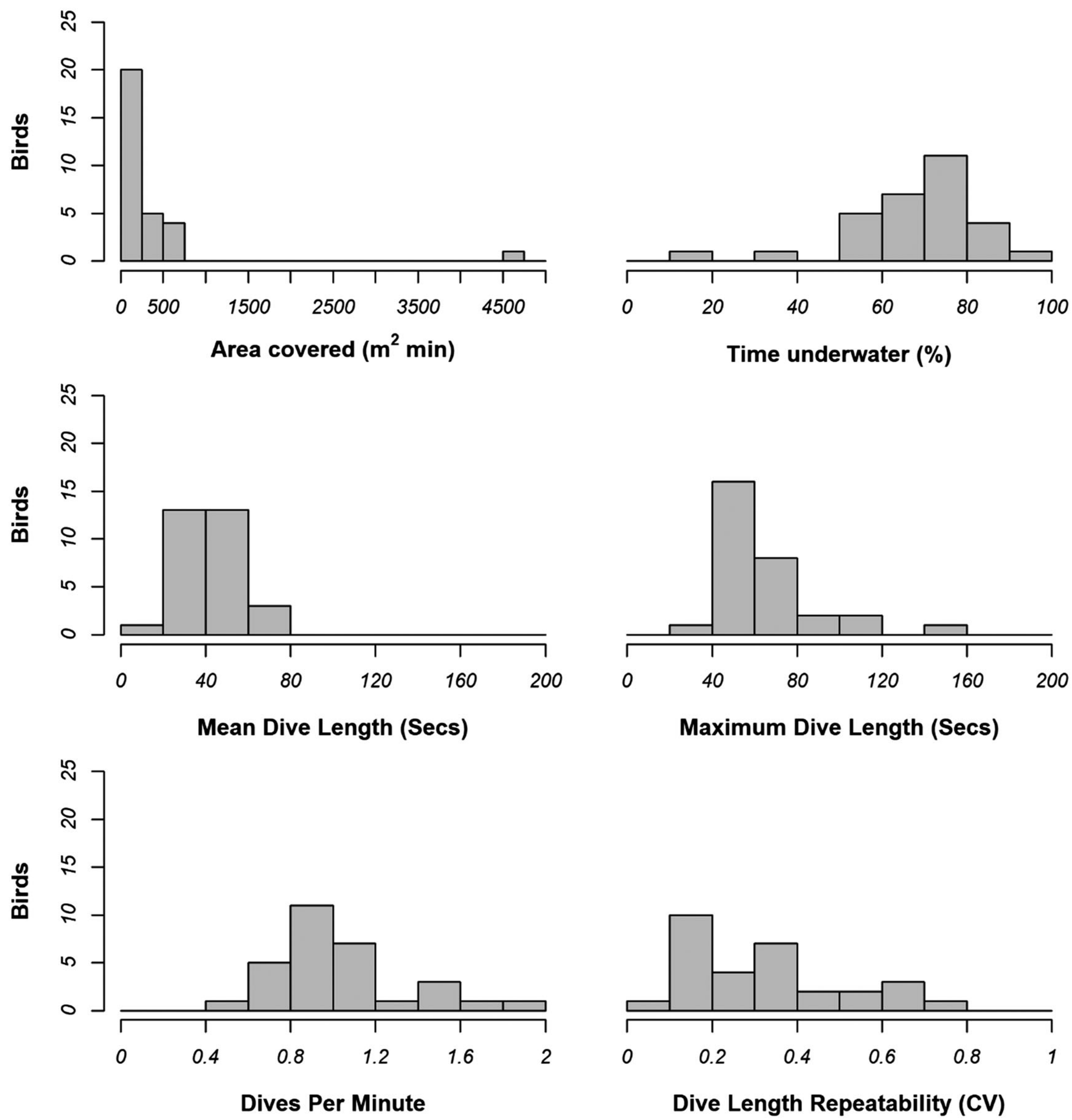

Figure 4. Summary of recorded behaviour and calculated movement of 30 European shag *Phalacrocorax aristotelis* alongside Ynys Moelfre, Anglesey, UK. Behaviour and movement were recorded and calculated, respectively, using rangefinder binoculars from a vantage point ~5 m above sea level.

calculations of the area covered in a small survey site. The area covered was then divided by the duration of the observation (min), providing the area covered per minute. The use of area covered per minute, rather than only area covered, was to account for birds that were tracked for different lengths of time. Mean and maximum dive lengths were provided directly from observations. The relative time underwater was calculated by dividing the total duration of dives (min) by observation time (min), whereas dive intensity represented the number of dives divided by the duration of the observation (min). Repeatability (R) in dive duration was represented using the coefficient of variance (CV) in measurements and was calculated using formula 2:

$$R = \frac{\sigma}{\mu} \tag{2}$$

where μ is the mean dive length and σ is the standard deviation of dive length. Values of R closer to 0 would indicate higher repeatability. All metrics are presented as mean ± standard deviation hereafter.

The metrics detailed above provided useful information on the movement of European Shags around Ynys Moelfre (Figure 4). Birds covered an area of 376 ± 846 m^2 per min, however, most birds (20/30) covered less than 250 m^2 per min, which is considerably smaller than the study site (0.26 km^2).

Birds showed relatively similar mean dive durations (41.89 ± 11.45 s), maximum dive duration (65.43 ± 22.27 s) and dive duration repeatability (0.32 ± 0.20). Birds were frequently diving, with 1.02 ± 0.32 dives per minute and 68 ± 15% of their time spent underwater. In summary, most birds concentrated their activities in relatively small areas, performing dives of consistent duration, and performing dives at frequent intervals. While information on sub-surface bird movement is needed for confirmation, above-surface bird movement is indicative of concentrated searches for fish and invertebrate prey on the seabed (Watanuki *et al.* 2008).

Although bird behaviour and movement can be recorded via biologgers, rangefinder binoculars can offer a more affordable, site-specific and rapid means to gather similar data. Rangefinder binoculars could be used to identify areas where birds are most vulnerable to human activities and development, e.g. proposed marine renewable energy sites. Caveats associated with rangefinder binoculars need acknowledging; in particular, the resolution of calculated locations will be coarse at low altitude and/or when birds are seen far away from the VP (over 350 m), and locations cannot be calculated without a clear view or approximation of the horizon. The possibility of recording movements of the same solitary bird numerous times across different surveys also creates possible non-independence amongst samples, whereas discriminating between individual birds in dense aggregations is challenging. Nevertheless, as rangefinder binoculars are portable, easily available and relatively affordable, they provide a potential means to rapidly gather useful and timely information across numerous locations in coastal environments.

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